



Global Ocean Monitoring and Observing
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

Emerging Technology - Advancing Technologies to Improve Ocean Monitoring

Christian Meinig, Scott Stalin, Noah Lawrence, Steven Anderson (CICOES), Nick Delich,
Dirk Tagawa, Mike Craig, Sean O'Neill,
& many scientists
NOAA
Pacific Marine Environmental Lab



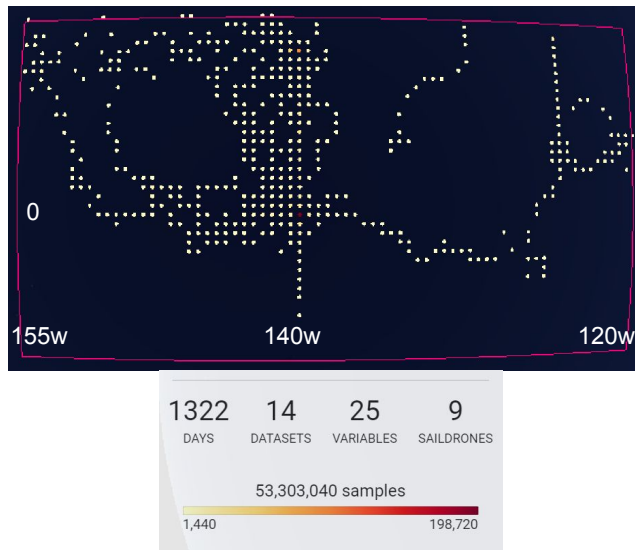
SAILDRONE

Developing Emerging Technology for Ocean Observing Research

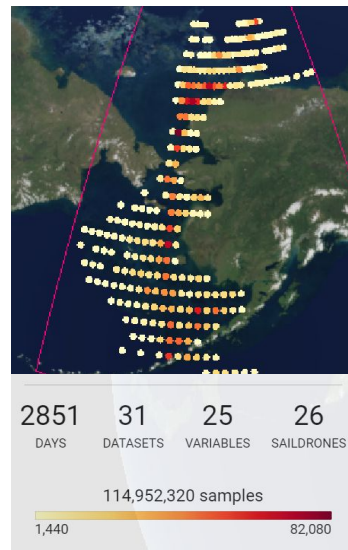
- Vision: To engineer cost effective platforms and sensors to deliver high quality EOVS, ECV at global scale
- GOMO provides critical funding to advance promising technologies into 'fit for purpose' scientific tools that informs policy and improves livelihoods

Example: Saildrone Observations(~6yrs)

Tropical Pacific



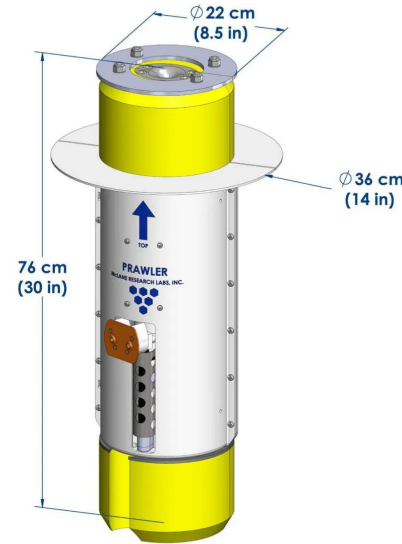
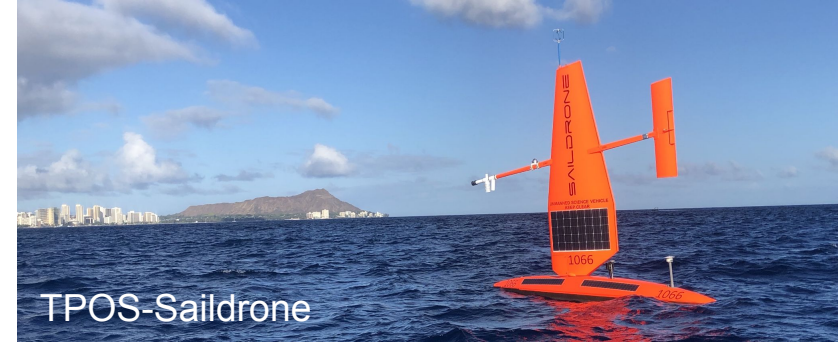
US Arctic



GOMO Investments: Emerging Tech Demonstration

Developing Emerging Technology for Ocean Observing Research

- Critical funding to engineering promising technologies into 'fit for purpose' scientific tools that inform policy and improve livelihoods
- Unique role of federal research labs/programs that have a long lever on the arc of system development to improve quality, relevance and performance of obs systems
- Close collaboration of scientists and engineers to systematize platform/ sensor development for EOVs, ECVs



GOMO Link: Sustained Funding

Saildrone: Arctic+TPOS

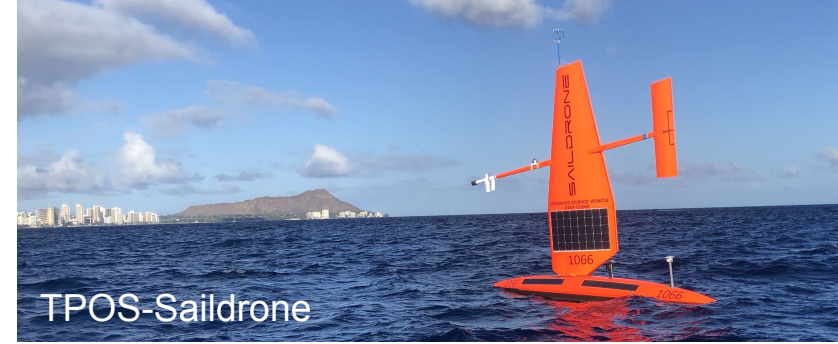
- Field missions in the Tropics(5 yrs) and Arctic(3 yrs) focused on scientific demonstration missions
- CRADAs(2)
- Transition Plans underway(4)

PRAWLER+TELOS: Tropics-to-Arctic Testing & Development

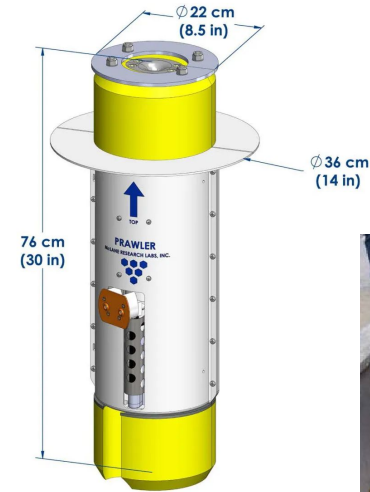
- CRADAs(2), Commercialization

Oculus: Arctic: Engineer new buoyancy engine

- CRADA(1), Partnership(UW & UW-APL), Kongsberg



TPOS-Saildrone

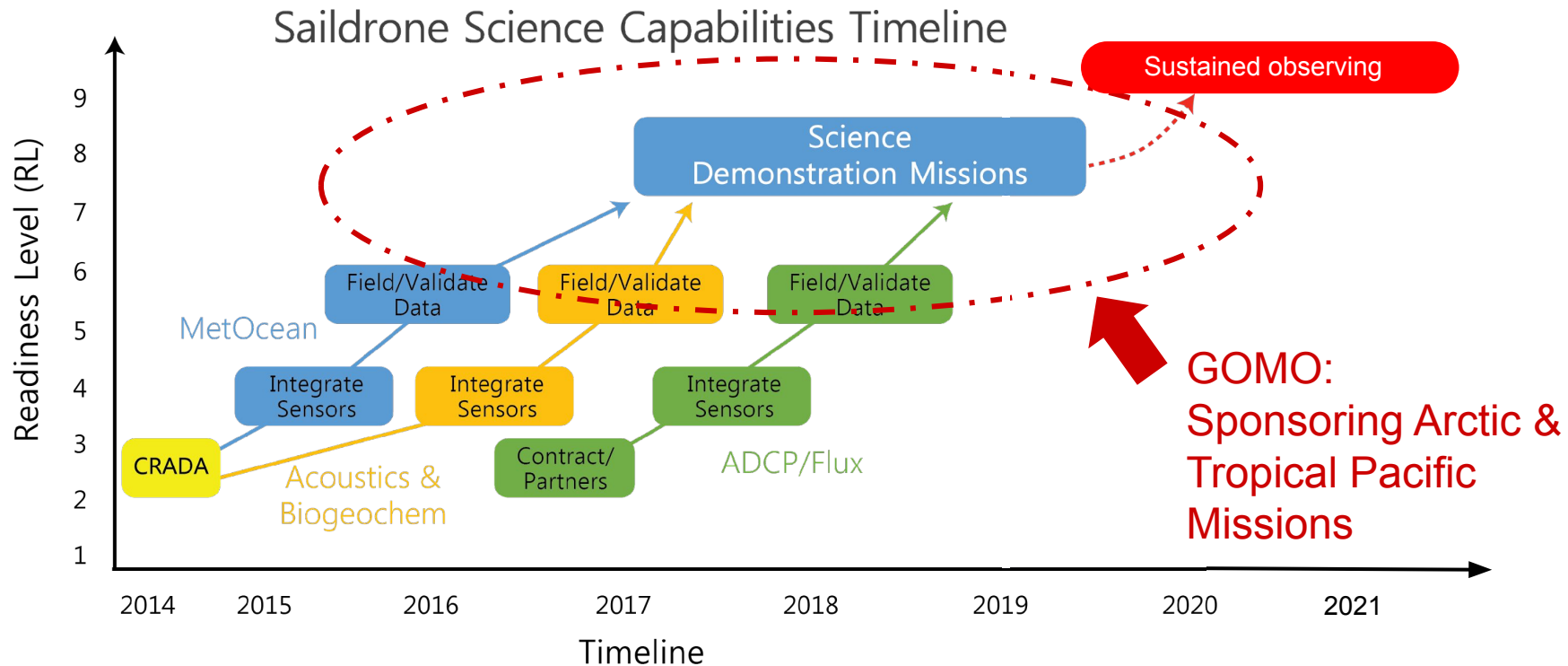


PRAWLER Mooring Profiler



Oculus-Glider

Saildrone Development: GOMO support at critical time

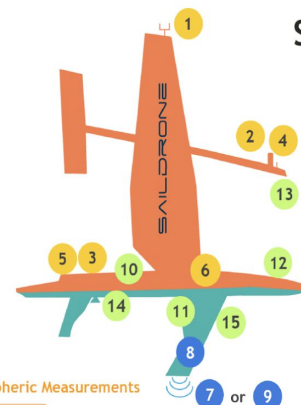


Saildrone: Science Demonstration Mission Impacts

- 5 TPOS & 3 Arctic Missions
- >10 peer reviewed publications
- 4 Transition Plans covering ~14 EO, ECVs
- >\$300M investment to date from private capital

Pioneered methods/techniques of validating and field testing climate quality sensors on USVs thru PPPs.

Meinig et al, 2019



Saildrone Sensor Suite

Specifications

Length: 7 m

Height: 4.6 m (above water line)

Depth: 2 m

Weight: 545 kg, (fully loaded)

Speed: Transit - 3 Kt, Max - 8 Kt

Payload Power: 30W Steady state

Payload Capacity: 100 kg

Max deployed duration: 12 months

Longest voyage: 16,100 km

Atmospheric Measurements

Wind Speed	1	Anemometer @ +5.0m Gill WindMaster 3D Ultrasonic 20Hz
Wind Direction	2	Sunshine Pyranometer @ +2.5m Delta-T Devices SPH1
Sunlight & Infrared Radiation	3	Pyrgometer @ +0.7m Eppley PIR
Air Temperature	4	Meteorological Probe @ +2.4m Rotronic HC2 - S3 with rad shield
Humidity	5	Digital Barometer @ +0.3m Vaisala BAROCAP PTB210
Air Pressure	6	CO ₂ System @ +0.5m PHEL ASVCO ₂
Air pCO ₂	7 or 9	

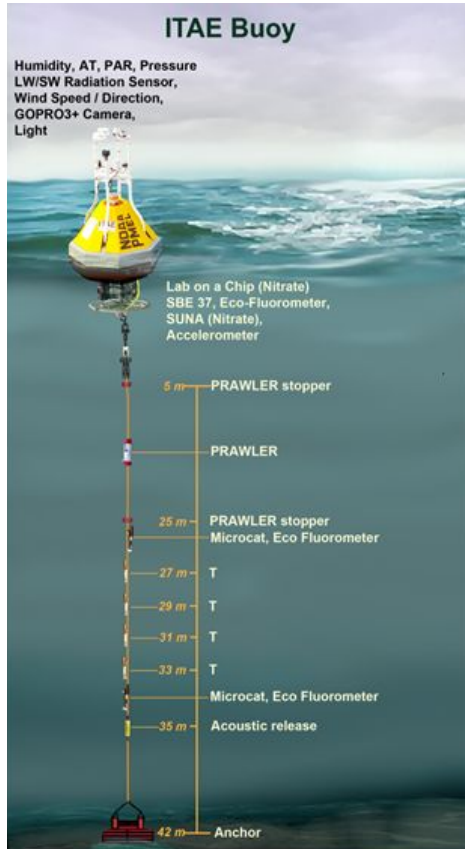
Oceanic Subsurface Measurements

Ocean Current	7	ADCP @ -1.8m Teledyne RDI 300 kHz Workhorse Sentinel
Water Temperature	8	RBR or SBE thermistors every 30cm from -0.3m to -1.8m
Fish Biomass	9	Scientific Echosounder @ -1.8m SHRAD WNNI Multi-beam Sonar @ -1.8m Norbit IWBMS
Bathymetry		

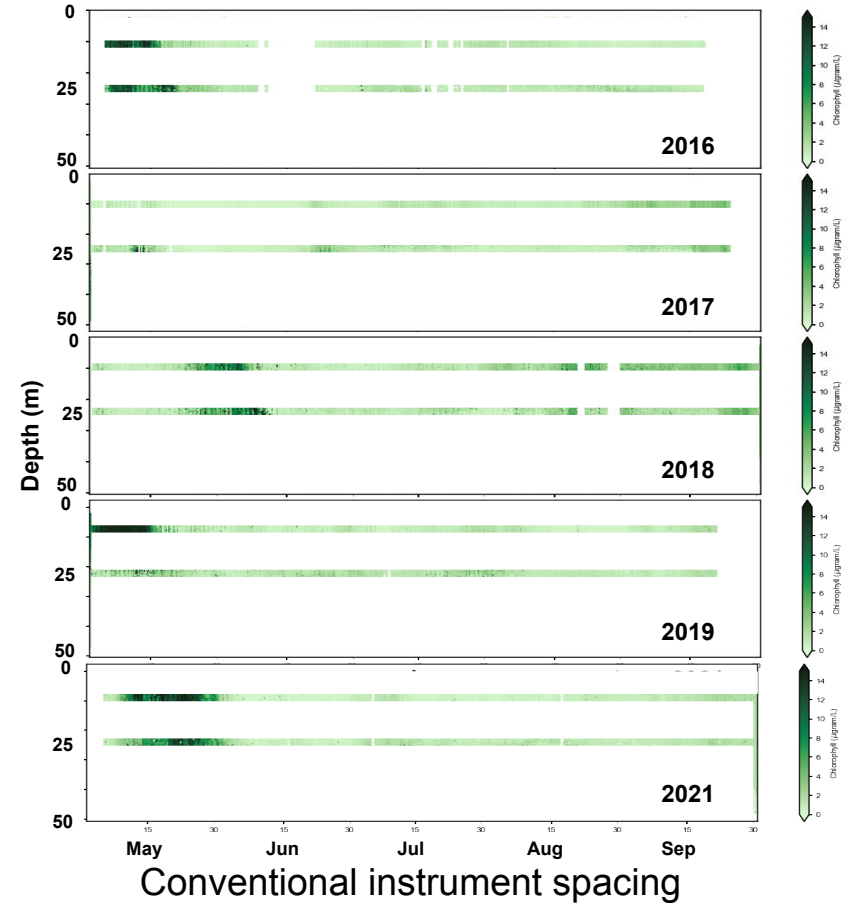
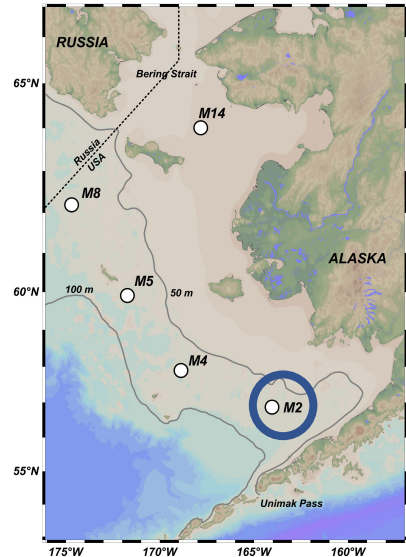
Oceanic Surface Measurements

Wave Height & Period	10	Dual GPS & IMU Vectornav / KVH
Seawater pCO ₂ & pH		
Dissolved Oxygen	11	CO ₂ System PHEL ASVCO ₂ @ -0.5m Honeywell DuraFet @ -0.5m Aanderaa Optode @ -0.5m Sea-Bird Scientific SBE PRAWLER @ -0.6m
Water Temperature		
Salinity		
Magnetic Field	12	Magnetometer Barrington MAG 648
Skin Temperature	13	SST IR Pyrometer @ +2.2m Heitronics KT15 II
Chla		
CDOM Concentration	14	Fluorometer and Backscatter @ -0.2m Sea-Bird Scientific WET Labs Eco Triplet
Red Backscatter		
Water Temperature		
Salinity	15	Thermosalinograph CTD @ -0.6m SBE37 & RBR conductivity

Mooring PRAWLER (PRofiler+crAWLER) (Performance Example)

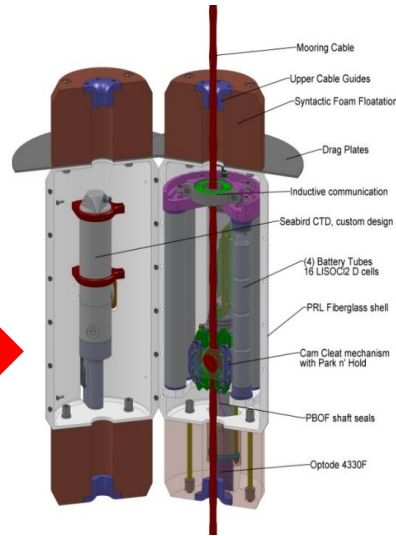
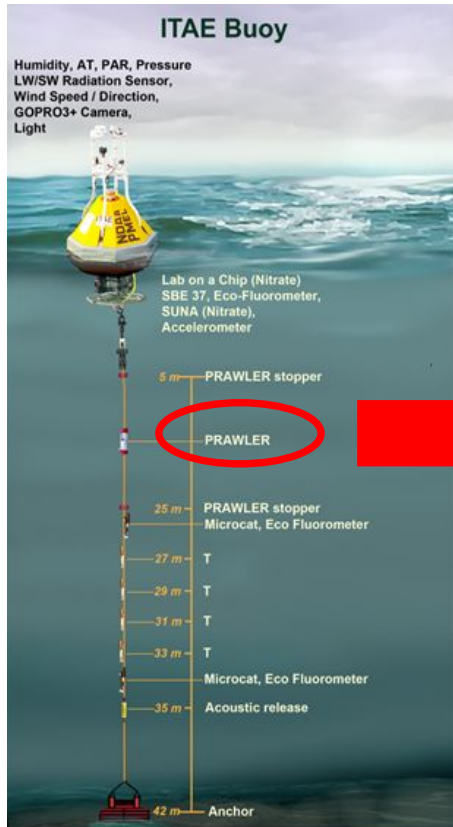


Ecosystem PRAWLER at M2 provided estimates of primary production filling a long-standing science gap in one of the largest fisheries in the US.



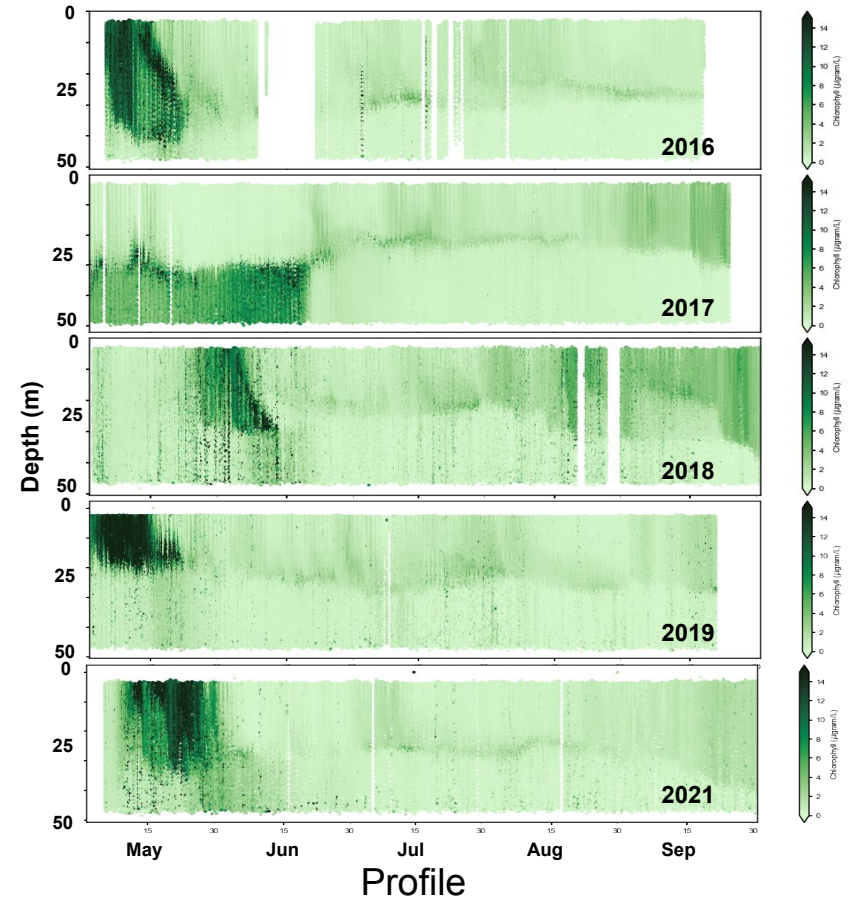
Nielsen (EcoFOCI/ABL NRC Assoc), Eisner (ABL), Mordy (UW/PMEL), Lomas (Bigelow), Juranek (OSU), Stabeno, Stalin, Meinig (PMEL)

Mooring PRAWLER (PRofiler+crAWLER) (Performance Example)



PMEL Design/Build

Improved resolution by
hourly profiles

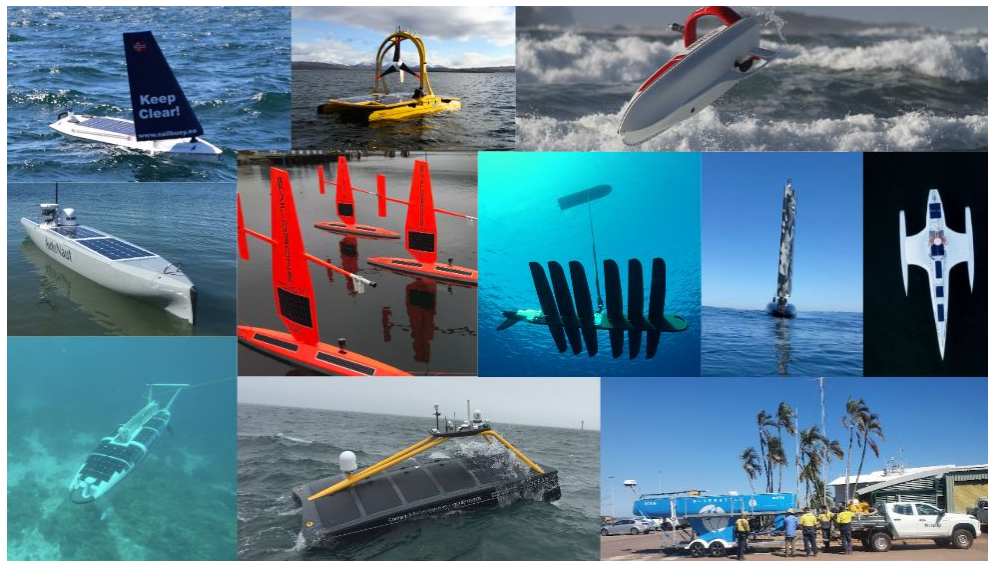


Nielsen (EcoFOCI/ABL NRC Assoc), Eisner (ABL), Mordy (UW/PMEL), Lomas (Bigelow), Juranek (OSU), Stabeno, Stalin, Meinig (PMEL)

Saildrone: Science Demonstration Mission Impacts

USVs ready for GOOS (caution on sensors & data!)

- Globally, >12 USVs operate commercially in the open ocean at RL 7-8.
- Climate quality sensors could be added per NOAA lessons on methods/techniques, comparisons, etc



Outcome:



Uncrewed Surface Vehicle Network for a remote, data-limited Global Ocean Observing System

Update on an emerging network for OCG

Ruth Patterson^{*1}, Meghan Cronin², Adrienne Sutton², Eugene Burger², Jack Reeves Eyre^{*3}, Dongxiao Zhang⁴, Jim Thomson⁵, Sebastiaan Swart⁶, Marcel du Plessis^{*6}, Tom Farrar⁷, Luc Lenain⁸, Laurent Grare⁸, Iwao Ueki⁹, Samantha Wills^{*4}, Chris Meinig², Jaime Palter¹⁰, Eric Lindstrom¹¹, Sarah Nicholson^{*12}, Pedro Monteiro¹²

Achievements and Impacts

A USV network **FILL GAPS** in space, time, disciplines and complement existing GOOS infrastructure

SPACE AND TIME

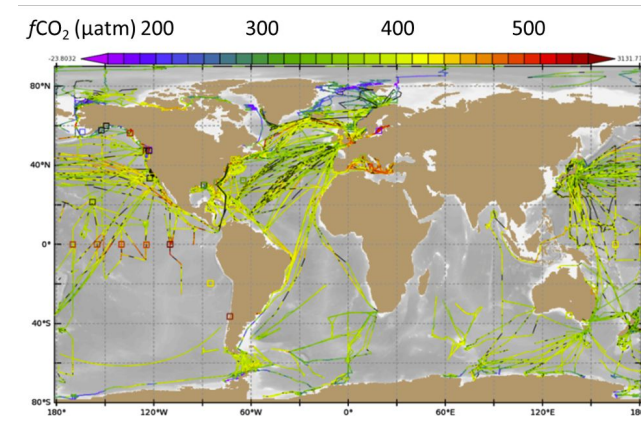
- **Remote locations** of global ocean not currently covered by GOOS infrastructure, **including semi-enclosed seas, gulfs, archipelagos and reef networks**
- **Under persistent cloud cover** that can obscure some satellite observations
- **Clusters of USV** that periodically come together to form **“Mesonet”**, then spread apart for greater coverage
- Pairs of USV, in loose **follow-the-leader** or **side-by-side formation** to observe EOY and spatial gradient

DISCIPLINARY

- **In severe weather and developing phenomena**
- **In frontal regions, and near ice edge**
- **In process studies**
- **Air-Sea interface studies at sub meter scale**

COMPLEMENTARY

- **Spatiotemporal coverage around fixed point moorings**
- **Air-sea surface surveys at subsurface moorings or glider profiles**
- **Acoustic gateway data transfers**



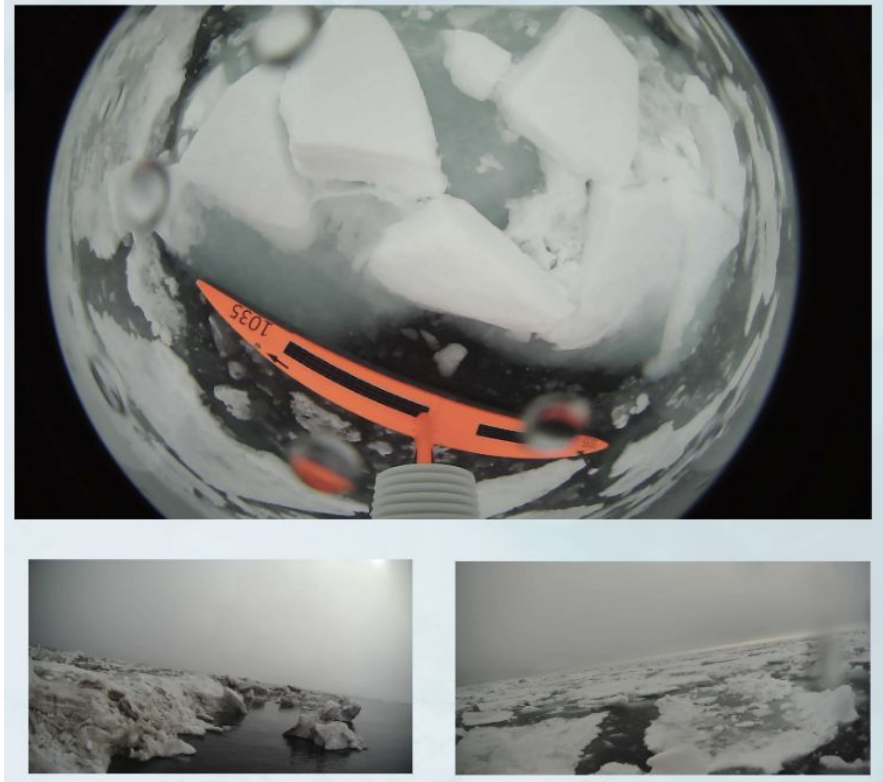
All seawater pCO₂ observations made in 2015

(From Patterson et al.)

Challenges:

Sustain funding is lacking for 'operations'

- Gaps in methods of assessing & prioritizing obs
- Gaps in communicating the value of observations to range of stakeholders
- Limited NOAA capacity of data assimilation specialists to characterize impacts



Future plans and opportunities

*“Patchwork of potentiality, and a network of
promise”*

Eric Lindstrom

- Next steps and future plans (next 5 years)
 - Grow from ‘patchwork of projects’ to a ‘cohesive USV science network’
 - Develop a COP as UN Decade Project (OASIS)
 - Establish a USV Data Acquisition Center that serves unique user needs
- How will these future plans advance the ocean observing enterprising?
 - Proven track record of going from ‘Ideation to Impact’
 - Sustainable, flexible, fit-for-purpose systems
 - Saildrones have proven to be ship-independent & responsive during COVID